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Appendix C

Steam Railroads: How Would a Weighted Ton-Mile Index Behave?

By Jacob M. Gould

The reasoning of Appendix A suggests that the best measure of what we really mean by the 'physical volume of freight traffic' would be an index of ton-miles in which each ton-mile was weighted by the revenue derived therefrom. It was explained in Chapter 4 that no breakdown of ton-miles is available except for the single year 1932. In consequence the unweighted ton-mile total has been regarded throughout this book as the basic measure of railroad freight traffic. It was also stated in Chapter 4 that the absence of a weighting system leads to an upward bias in our ton-mile index, at least for the period 1919-39. The purpose of the present Appendix is to justify this statement.

For any given commodity, let

q, be the number of tons originated;

qh, its ton-mileage;

pqh, revenue accruing from its transportation.

If we had such data for each year we could isolate by successive division the three components of freight revenue. Thus h is the *average* haul associated with the shipment of q tons of the commodity, and p is the *average* revenue per ton-mile realized from its transportation. A certain amount of variation lies behind these averages; however, it will be necessary to treat ton-miles for individual commodities as homogeneous. That is to say, it will be impossible to take account of differences in revenue per ton-mile — caused by varying handling charges, lengths of haul, and so forth — among individual shipments of any one commodity. We assume that the dispersion of p within commodity groups is small compared with its dispersion between such groups.

If we denote base-year quantities by small letters and given-year quantities by capitals, the simple Laspeyres index has the form

(1) $\Sigma QHp/\Sigma qhp$, in which the summation extends over all the

commodities entering into the index. This is the 'weighted ton-mile', or 'ideal', index which cannot in fact be constructed.

Among indexes capable of actual construction from available data,

(2) $\Sigma QH/\Sigma qh$

is the unweighted ton-mile index, which we have treated as basic in Chapter 4. In the alternative index there discussed,

(3) $\Sigma Qhp/\Sigma qhp$

each class of tonnage originated is weighted by the corresponding base-year figure for revenue per ton of freight originated. This index can be obtained because data on tonnage originated broken down by commodities are available every year, and revenue totals for all commodities are available for some years, thus providing base-year weights.

It is apparent from inspection that (2) does not take into account variations in p over all classes of commodities and will differ from (1) as the relative proportions of those classes change, whose freight charges in the base year were on different levels.

Again it is apparent from inspection that (3) is deficient, in that it fails to account for the change in h occurring between the given year and base year, although it does assign the desired pecuniary weights to the various classes of commodities. This deficiency is accentuated as the period separating the years compared widens, for the secular increase in *average* haul has been quite marked over the period in question (see Table C-3). Formula (2) will, of course, adequately reflect this change, but takes no account of dispersion in rates even between one commodity and another.

CAN WE MEASURE THE BIAS IN A WEIGHTED INDEX OF TONS ORIGINATED?

In any year we may derive the average haul for all commodities by dividing total ton-mileage by total tons originated. The question arises whether (3), with a simple adjustment for change in average haul of all commodities, will approach our 'ideal' formula. Such an adjusted index would be afforded by:

$$(4)\quad \frac{\Sigma Qhp}{\Sigma qhp} \cdot \frac{\Sigma QH}{\Sigma Q} \Bigg/ \frac{\Sigma qh}{\Sigma q}$$

Some light is shed on the relation between (4) and the 'weighted ton-mile' index, (1), by the following considerations. Formula (1) may be expressed as:

$$\frac{\Sigma QHp}{\Sigma qhp} = \frac{\Sigma Qhp(H/h)}{\Sigma qhp}$$

By substitution of Qhp and H/h for x and y in the correlation formula

$$\frac{1}{n}\Sigma x \, \Sigma y = \Sigma xy - r_{xy}\sigma_x\sigma_y$$

we get the identity

$$\frac{\Sigma Qhp}{\Sigma qhp} \cdot \frac{1}{n} \Sigma \frac{H}{h} = \frac{\Sigma QHp}{\Sigma qhp} - R$$

where the remainder denoted by R is a quantity that varies with the degree of correlation existing between the expressions Qhp and H/h; i.e., between the given year quantity valued at the base-year price and the change in the length of haul. To the extent that this correlation approaches zero, formula (4) may be said to approach the 'weighted ton-mile' index, with the difference that the ratio of weighted aggregates, $\frac{\Sigma QH}{\Sigma Q} \Big/ \frac{\Sigma qh}{\Sigma q}$ is replaced by the average of relatives, $\frac{1}{n} \Sigma \frac{H}{h}$ as a measure of the change in h. The latter qualification to the use of (4) as an approximation to (1) is not, however, as serious an objection as the assumption that the coefficient of correlation between Qhp and H/h will be small enough to render negligible the above remainder, R. The possibility of such correlation is enhanced by the fact that the distribution of revenue totals in any year is highly nonnormal,[1] being characterized by a heavy concentration of items at the extreme right of the distribution and a few observations (such as bituminous coal) at the extreme left (Table C-2). The use of the weighted index of tonnage originated is thus seen to involve a degree of error about which we know little. Nor does it seem that a simple correction for change in average haul could prove adequate.

[1] See F. C. Mills, *Statistical Methods* (Holt, 1938), pp. 370-4, for a discussion of the derivation of (spuriously) high correlation coefficients based on nonnormal distributions.

THE BIAS IN AN UNWEIGHTED INDEX OF TON-MILES

It is somewhat easier to estimate the bias in our basic index, which relies on a simple ton-mile aggregate

$$(2)\quad \frac{\Sigma QH}{\Sigma qh}.$$

We shall show that such an index understates by 5 to 10 percent the decline in freight traffic over the period 1919-39 that would be reported by a weighted ton-mile index.

The starting point of this inquiry must be the detailed commodity figures collected by the Federal Coordinator of Transportation for 1932. This canvass produced, for the first and only time, p, q, and h data for the 156 ICC carload commodity classifications (Tables C-1 and C-2). In the grouping process, all ton-miles associated with a particular commodity are supposed concentrated at their mean rate per ton-mile. Consequently the distribution given is merely an approximation to that which would be obtained if individual shipments were classified immediately according to their ton-mile rates.

While, therefore, the classification of Table C-2 is essentially by commodities, as in Table C-1, these no longer appear explicitly. We may note, however, two commodity classifications of special importance: bituminous coal, which is grouped separately at one end of the distribution, and the less-than-carload class in the 3.750-3.899 cents per ton-mile interval. We single these two groups out for special attention because in this way the entire price distribution is seen to fall into three significant components. Bituminous coal, which we shall refer to as Group I, may be regarded as homogeneous. Group II consists of all commodities other than bituminous coal, less-than-carload lots, and two relatively minor commodity groups (passenger automobiles and explosives) transported at what amount to less-than-carload rates. While the dispersion of Group II is relatively wide, the 'normality'[2] of its distribution about the modal interval suggests that it may be treated as homogeneous. Group III at the upper end of the range is domi-

[2] This is a rather loose use of the term, for the Group II distribution is obviously skewed to the left. There is of course a danger involved in regarding this group as homogeneous, i.e., treating its average (weighted) price as representative of the entire group, and associating the entire group frequency with it. The danger, however, is far less than had we retained bituminous coal in the group.

Table C-1

STEAM RAILROADS: FREIGHT TRAFFIC BY INDIVIDUAL COMMODITIES, 1932[a]

ICC Ref. No.	*Commodity or Group*	*Tonnage Orig.* (th.)	*Ton-miles* (mil.)	*Freight Revenue* ($ th.)	*Rev. per Ton-mile* (cents)	*Av. Haul* (miles)
10	Wheat	19,913	6,359	66,571	1.05	319
20	Corn	9,736	2,834	29,862	1.05	291
30	Oats	3,531	1,162	10,774	0.93	329
40	Barley and rye	1,585	439	4,650	1.06	277
41	Rice	591	189	2,474	1.31	320
42	Grain, NOS	83	42	397	0.94	505
50	Flour, wheat	8,811	5,011	34,479	0.69	569
51	Meal, corn	196	89	548	0.61	456
52	Flour and meal, edible, NOS	447	254	1,872	0.74	567
60	Cereal food preparations, edible, NOS	742	466	4,430	0.95	627
61	Mill products, NOS	6,214	2,534	17,926	0.71	408
70	Hay and alfalfa	1,432	536	7,415	1.38	375
71	Straw	148	31	541	1.74	210
80	Tobacco, leaf	633	232	5,113	2.20	367
90	Cotton in bales	2,562	1,052	18,965	1.80	411
91	Cotton linters	249	172	1,828	1.06	692
100	Cottonseed	1,751	177	3,765	2.13	101
101	Cottonseed meal and cake	1,450	668	6,135	0.92	462
110	Oranges and grapefruit	1,805	3,835	48,083	1.25	2,126
111	Lemons, limes, and citrus fruits, NOS	225	536	5,865	1.09	2,387
120	Apples, fresh	1,388	1,614	20,347	1.26	1,162
121	Bananas	675	469	10,165	2.17	694
122	Berries, fresh	51	62	1,285	2.08	1,200
123	Cantaloupes and melons, NOS	300	729	8,624	1.18	2,434
124	Grapes, fresh	648	1,682	19,410	1.15	2,597
125	Peaches, fresh	262	220	4,011	1.82	843
126	Watermelons	363	393	4,522	1.15	1,084
127	Fruits, fresh, domestic, NOS	458	803	10,152	1.26	1,754
128	Fruits, fresh, tropical, NOS	39	59	722	1.22	1,519
130	Potatoes, other than sweet	3,516	2,607	32,246	1.24	741
140	Cabbage	380	368	5,085	1.38	970
141	Onions	379	384	4,491	1.17	1,013
142	Tomatoes	273	518	6,895	1.33	1,894
143	Vegetables, fresh, NOS	1,665	3,433	44,085	1.28	2,063
150	Beans and peas, dried	586	521	5,609	1.08	888
151	Fruits, dried or evaporated	521	434	4,859	1.12	834
152	Vegetables, dry, NOS	213	147	2,108	1.44	689
160	Vegetable oil, cake and meal, except cottonseed	290	116	986	0.85	399
161	Peanuts	231	165	2,484	1.50	715
162	Flaxseed	288	88	1,096	1.25	304
163	Sugar beets	5,422	253	3,460	1.37	47
164	Products of agriculture, NOS	3,139	1,339	15,719	1.17	426
	PRODUCTS OF AGRICULTURE, TOTAL	83,192	43,023	480,052	1.12	517

Table C-1 – RAILROAD FREIGHT TRAFFIC (continued)

ICC Ref. No.	*Commodity or Group*	*Tonnage Orig.* (th.)	*Ton-miles* (mil.)	*Revenue Freight* ($ th.)	*Rev. per Ton-mile* (cents)	*Av. Haul* (miles)
170	Horses, mules, ponies and asses	233	138	2,749	1.99	594
180	Cattle and calves, single-deck	4,888	1,997	32,916	1.65	409
181	Calves, double-deck	59	33	458	1.39	554
190	Sheep and goats, single-deck	202	92	1,556	1.70	453
191	Sheep and goats, double-deck	914	584	8,232	1.41	639
200	Hogs, single-deck	1,582	386	8,897	2.31	244
201	Hogs, double-deck	2,320	1,255	17,831	1.42	541
210	Fresh meats, NOS	2,678	2,457	40,417	1.64	918
220	Meats, cured, dried or smoked	587	593	8,498	1.43	1,011
221	Butterine and margarine	12	9	222	2.38	761
222	Packing house products, edible, NOS[b]	1,027	818	12,490	1.53	797
230	Poultry, live	112	135	3,040	2.26	1,207
231	Poultry, dressed	285	351	7,349	2.09	1,232
240	Eggs	459	621	11,438	1.84	1,353
250	Butter	607	563	12,230	2.17	927
251	Cheese	183	150	3,032	2.01	819
260	Wool	263	224	4,684	2.09	851
270	Hides, green	519	322	4,531	1.41	620
271	Leather	130	81	1,286	1.60	617
280	Fish or sea-animal oil	83	80	636	0.79	966
281	Animals, live, NOS	10	3	74	2.29	340
282	Animal products, NOS[c]	1,042	477	7,961	1.67	457
	ANIMAL AND PRODUCTS, TOTAL	18,195	11,368	190,528	1.68	625
290	Anthracite coal	54,974	9,571	107,913	1.13	174
300	Bituminous coal	208,383	75,412	491,048	0.65	362
310	Coke	7,420	1,354	15,386	1.14	182
320	Iron ore	5,919	792	6,563	0.83	134
330	Copper ore and concentrates	1,987	59	551	0.94	30
331	Lead ore and concentrates	917	48	663	1.39	52
332	Zinc ore and concentrates	794	279	1,831	0.66	352
333	Ores and concentrates, NOS	1,075	515	3,410	0.66	479
350	Gravel and sand[d]	28,589	1,992	23,475	1.18	70
351	Stone, broken, ground, or crushed	15,161	1,309	13,555	1.04	86
352	Stone, rough, NOS	2,507	342	3,407	1.00	136
353	Stone, finished, NOS	510	265	2,598	0.98	521
360	Petroleum, crude	2,666	1,075	8,605	0.80	403
370	Asphalt	2,601	768	9,618	1.25	295
380	Salt	3,004	1,452	13,945	0.96	483
390	Phosphate rock, crude	2,853	319	2,826	0.89	112
391	Sulphur	1,434	351	2,796	0.80	245
392	Products of mines, NOS	12,544	2,832	23,460	0.83	226
	PRODUCTS OF MINES, TOTAL	353,336	98,736	731,652	0.74	279

Table C-1 — RAILROAD FREIGHT TRAFFIC (continued)

ICC Ref. No.	*Commodity or Group*	*Tonnage Orig.* (th.)	*Ton-miles* (mil.)	*Freight Revenue* ($ th.)	*Rev. per Ton-mile* (cents)	*Av. Haul* (miles)
400	Logs	5,195	289	3,045	1.05	56
401	Posts, poles and piling	1,508	761	7,297	0.96	505
402	Wood (fuel)	1,399	125	1,377	1.10	89
410	Ties, railroad	837	262	2,763	1.05	313
420	Pulpwood	3,454	514	4,588	0.89	149
430	Lumber, shingles, and lath	11,446	8,549	67,862	0.79	747
431	Box, crate, and cooperage materials	1,712	1,089	11,143	1.02	636
432	Veneer and built-up wood	108	132	978	0.74	1,225
440	Rosin	251	135	1,352	1.10	540
441	Turpentine	44	45	540	1.19	1,037
442	Crude rubber (not reclaimed)	375	207	2,773	1.34	552
443	Products of forests, NOS	1,047	337	3,991	1.18	322
	FOREST PRODUCTS, TOTAL	27,375	12,446	107,710	0.87	455
450	Refined petroleum and gasoline	36,465	12,794	192,273	1.50	351
451	Fuel, road, and residual oils, NOS	7,985	2,267	27,673	1.22	284
452	Lubricating oils and greases	2,510	1,222	15,546	1.27	487
453	Petroleum products, NOS	186	78	971	1.25	418
460	Cottonseed oil	894	466	5,811	1.25	521
461	Linseed oil	118	60	769	1.28	512
462	Vegetable oils, NOS	330	355	2,377	0.67	1,076
470	Sugar (beet or cane)	3,725	2,111	25,310	1.20	567
471	Table syrups and edible molasses	487	349	3,246	0.93	716
472	Molasses and beet residual	450	156	1,551	0.99	347
490	Iron, pig	1,460	295	2,833	0.96	202
491	Iron and steel, 6th class, NOS	1,301	128	1,880	1.47	98
500	Rails, fastenings, frogs, and switches	394	132	1,481	1.12	336
510	Cast-iron pipe and fittings	442	263	3,166	1.20	596
511	Iron and steel pipe and fittings, NOS	1,361	710	10,547	1.49	522
512	Iron and steel: nails and wire not woven	657	278	4,070	1.47	422
513	Iron and steel, 5th class, NOS[e]	9,428	2,892	42,298	1.46	307
520	Copper: ingot, matte, and pig	200	236	1,676	0.71	1,181
521	Copper, brass and bronze[f]	128	48	690	1.45	373
522	Lead and zinc: ingot, pig, or bar	590	562	3,436	0.61	953
523	Aluminum: ingot, pig, or slab	16	13	209	1.60	809
530	Machinery and boilers	1,074	631	10,850	1.72	587

Table C-1 – RAILROAD FREIGHT TRAFFIC (continued)

ICC Ref. No.	*Commodity or Group*	*Tonnage Orig.* (th.)	*Ton-miles* (mil.)	*Freight Revenue* ($ th.)	*Rev. per Ton-mile* (cents)	*Av. Haul* (miles)
540	Cement	11,529	2,257	31,797	1.41	196
550	Brick, common	1,009	188	2,068	1.10	187
551	Brick, NOS, and building tile	2,416	767	7,191	0.94	317
552	Artificial stone, NOS	139	48	547	1.13	348
560	Lime, common (quick or slaked)	1,116	395	3,842	0.97	354
561	Plaster and dry kalsomine	609	285	2,705	0.95	469
570	Sewer pipe and drain tile[g]	622	212	2,702	1.27	341
580	Agricultural implements and parts, NOS	184	109	1,940	1.78	589
581	Vehicles, horse-drawn, and parts, NOS	12	8	148	1.76	706
582	Tractors and parts	112	75	1,302	1.73	673
583	Railway car wheels, axles, and trucks	132	37	607	1.63	281
590	Automobiles (passenger)	709	583	21,821	3.74	823
591	Autotrucks	58	52	1,468	2.81	906
592	Automobiles and trucks, KD, and parts, NOS	1,311	872	14,428	1.65	665
593	Automobile and truck tires	218	199	3,620	1.82	912
610	Furniture, metal	71	46	935	2.01	650
611	Furniture, other than metal	308	248	5,955	2.40	804
620	Beverages	360	156	2,234	1.43	433
630	Ice	1,474	74	1,691	2.28	50
640	Fertilizers, NOS	4,966	1,420	15,821	1.11	286
650	Newsprint paper	1,621	1,147	11,348	0.99	708
651	Printing paper, NOS	1,223	634	7,478	1.18	519
660	Alcohol, denatured or wood	230	121	1,617	1.34	526
661	Sulphuric acid	1,206	195	3,058	1.57	162
662	Explosives, NOS	136	66	2,484	3.79	483
670	Cotton cloth and fabrics, NOS	300	195	3,866	1.98	650
671	Bagging and bags, burlap, jute	208	123	1,782	1.45	592
680	Canned food products, NOS	3,239	2,197	27,442	1.25	679
690	Tobacco, manufactured products	151	191	3,484	1.83	1,259
691	Paints in oil and varnishes	196	125	1,706	1.36	639
692	Furnace slag	2,071	177	1,841	1.04	85
693	Scrap iron and scrap steel	3,490	491	6,832	1.39	141
694	Paper bags and wrapping paper	1,077	638	7,611	1.19	593
695	Paperboard, pulpboard, and wallboard	1,593	731	8,518	1.16	459
696	Roofing materials[h]	1,102	464	6,120	1.32	421
697	Building woodwork (millwork)	155	224	1,692	0.75	1,451

Table C-1 — RAILROAD FREIGHT TRAFFIC (concluded)

ICC Ref. No.	*Commodity or Group*	*Tonnage Orig.* (th.)	*Ton-miles* (mil.)	*Freight Revenue* ($ th.)	*Rev. per Ton-mile* (cents)	*Av. Haul* (miles)
698	Soap and washing compounds	865	428	6,338	1.48	495
699	Glass, flat, other than plate	203	126	1,664	1.32	621
700	Glass: bottles and jars	1,154	646	8,225	1.27	560
701	Manufactures and miscellaneous, NOS	26,202	12,421	173,848	1.40	474
	MANUFACTURES AND MISCELLANEOUS, TOTAL	143,979	55,420	768,436	1.39	385
	TOTAL CARLOAD	626,078	220,994	2,278,377	1.03	353
	LESS-THAN-CARLOAD	15,115	6,590	250,861	3.81	436
	GRAND TOTAL	641,193	227,584	2,529,238	1.11	355

NOS: not otherwise specified.
KD: knocked down.

[a] For carload traffic this table is transcribed from Federal Coordinator of Transportation, *Freight Traffic Report,* App. I, pp. 72-3. The result of a separate canvass, the data are approximately comparable with figures for Class I roads published in the *Statistics of Railways.* However, the Federal Coordinator failed to secure data for three roads: Green Bay and Western; New York Connecting; and Toledo, Peoria and Western. Partly on this account originated tonnage shown here is 99.2 percent, freight revenue 99.9 percent, of the corresponding totals for all carload traffic for 1932 as published by the ICC in the *Statistics of Railways.* For less-than-carload traffic, originating tonnage and revenue, as reported in the *Statistics of Railways* were each multiplied by 99.2 percent; average haul was taken from Federal Coordinator of Transportation, *Merchandise Traffic Report* (1934), p. 134; the remaining entries were computed by us.

[b] Does not include canned meats.

[c] Does not include fertilizer materials.

[d] Does not include glass or molding sand.

[e] Includes tin and terne plate.

[f] Bars, sheets, and pipes.

[g] Not made of metal.

[h] Includes building paper.

nated by the LCL class. In our distribution the frequency (i.e., number of ton-miles) of the LCL class is concentrated in one interval, no further breakdown of this group being possible. LCL ton-mileage is probably distributed over the entire upper range of the price scale.

By adopting 1932 as our base year (which implies the assumption that the distribution of prices in this year is representative of the entire period in question) we can investigate the possible differences between an unweighted index and one in which the three most significant groups are properly weighted. This can be done by expressing the ratio between these two indexes in terms of the price and value relationships of the three components in the base year and their quantity movements over the period in question.

Table C-2

STEAM RAILROADS: FREIGHT TRAFFIC BY REVENUE PER TON-MILE, 1932[a]

	Revenue per Ton-mile (cents)	*Ton-miles* (mil.)	*Revenue*[b] (mil. $)	*Tonnage Originated* (mil.)	*Average Haul* (miles)
		Group I (bituminous coal)			
	0.651	75,412	491.0	208.38	362
		Group II			
	0.600-0.749	9,967			
	0.750-0.899	14,852			
	0.900-1.049	17,680			
	1.050-1.199	19,769			
	1.200-1.349	31,814			
	1.350-1.499	24,196			
	1.500-1.649	18,557			
	1.650-1.799	2,295			
	1.800-1.949	2,283			
	1.950-2.099	1,166			
	2.100-2.249	1,441			
	2.250-2.399	607			
	2.400-2.549	248			
	2.550-2.699	0			
	2.700-2.849	52			
SUMMARY	1,216	144,927	1,763.1	416.85	348
		Group III			
	3.600-3.749	583			
	3.750-3.899	6,656[c]			
SUMMARY	3.800	7,239	275.1	15.96	454
TOTAL, ALL GROUPS	1.111	227,578	2,529.2	641.19	355

[a] Computed from Table C-1, except for less-than-carload traffic, for which see note c. The interval 2.85 to 3.60 cents per ton-mile contains no traffic.
[b] The group revenue totals do not exactly equal those obtained directly from the distribution because of the grouping error involved in the latter.
[c] Includes an estimated LCL figure of 6,590 million ton-miles, obtained by multiplying the ICC tonnage originated (reduced by slightly less than 1 percent to allow for roads that did not report to the Federal Coordinator) by an average haulage figure of 436 miles (*Merchandise Traffic Report,* p. 134).

For three 'commodities' (the three groups of Table C-2) designated by subscripts, the ratio between the weighted and unweighted indexes,

$$S = \frac{Q_1H_1p_1 + Q_2H_2p_2 + Q_3H_3p_3}{q_1h_1p_1 + q_2h_2p_2 + q_3h_3p_3} \Bigg/ \frac{Q_1H_1 + Q_2H_2 + Q_3H_3}{q_1h_1 + q_2h_2 + q_3h_3}$$

$$= \frac{ab + ad + cd}{1 + d + cd} \cdot \frac{1 + df + cdef}{ab + adf + cdef},$$

where

$$\left.\begin{aligned} a &= p_1/p_2 \\ b &= p_2/p_3 \end{aligned}\right\} \text{the ratios of base-year prices,}$$

$$\left.\begin{aligned} c &= p_1q_1h_1/p_2q_2h_2 \\ d &= p_2q_2h_2/p_3q_3h_3 \end{aligned}\right\} \text{the ratios of base-year revenues,}$$

and

$$\left.\begin{aligned} e &= \frac{Q_1H_1}{q_1h_1} \Bigg/ \frac{Q_2H_2}{q_2h_2} \\ f &= \frac{Q_2H_2}{q_2h_2} \Bigg/ \frac{Q_3H_3}{q_3h_3} \end{aligned}\right\} \text{the ratios of the quantity relatives between given and base years.}$$

Since the first four variables are known for the base year 1932, S may be expressed as a function of e and f alone.

$$S = .586 \frac{1 + 6.409f + 1.785ef}{.176 + 3.431f + 1.785ef}$$

We lack a breakdown of ton-miles by individual commodities for years other than 1932, i.e., we do not know the H's which determine the values of e and f. Yet we can establish limits for these two quantities. For instance, if 1919 is the given year, it is safe to say that over the period 1919-32 more LCL freight (Group III) than general freight (Group II) was diverted to highways. Therefore we may assume

$$\frac{Q_3H_3}{q_3h_3} > \frac{Q_2H_2}{q_2h_2}$$

and set $f < 1$ for this comparison.

Next, by imposing the limits $1.05 > S > .95$ we can determine the range over which e may vary and still permit the unweighted index to fall within 5 percent of the 'true' index. For a bias no larger than this,

if f is	1.0	0.9	0.6	0.5
e must lie between	0.67	0.73	1.00	1.16
and	1.42	1.49	1.85	2.06

The above table reveals something of the assumptions involved in the use of the unweighted index to represent the 'true' index for the period 1919-32; namely, that a decline of f below 1.0 must be compensated by a movement in the other direction on the part of e, if the index is to remain within the 5 percent limits of error. For instance, if f fell as low as 0.6 for the comparison of any year with 1932, e must be greater than 1.0,[8] i.e., $\frac{Q_1H_1}{q_1h_1} > \frac{Q_2H_2}{q_2h_2}$, which in turn means that the movement of bituminous coal from the given year to the base year 1932 must lag behind that for railroad traffic as a whole. It will appear, on the contrary, that shipments of bituminous coal, far from lagging behind other railroad traffic, maintained a relative advantage over other traffic, thus causing e to fall below the level necessary to keep S within the 5 percent limits of error.

Incidence of the Change in Haul

The quantity movements of railroad traffic, as we define them, are functions of the changes in the quantities of tons originated and in the average haul associated with the various groups of originated tonnage. In the absence of specific information concerning length of haul, it is necessary to examine the economic forces operating to influence the haul, with a view toward making the best possible hypotheses concerning its movement.

The average haul for all commodities transported by the railroads considered as one system (obtained by dividing total ton-miles by total tons originated) increased from 277.3 miles in 1911 to 375.8 miles in 1938, or 35.5 percent. As Table C-3 shows, the total gain may conveniently be assigned to the two periods marked off by the year 1923. The initial large increase in haul seems to be

[8] The upper limit of e is ignored in the discussion because the data suggest that only the lower limit is relevant in the period considered.

Table C-3

STEAM RAILROADS: FREIGHT TRAFFIC, AVERAGE HAUL, 1899-1946[a]

Miles

Year Ending June 30	*Class I, II, and III Roads*	*Class I Roads Only*	*Calendar Year*	*Class I, II, and III Roads*	*Class I Roads Only*
1899	246.6	....	1920	303.5	326.8
			1921	304.1	326.4
1900	242.7	....	1922	307.8	331.4
1901	252.0	....	1923	299.9	322.7
1902	239.1	....	1924	304.4	327.1
1903	242.4	....	1925	308.9	331.8
1904	244.3	....	1926	310.8	332.1
1905	237.6	....	1927	314.8	334.5
1906	240.9	....	1928	318.0	336.7
1907	242.1	....	1929	317.2	334.1
1908	253.9	....			
1909	251.1	....	1930	316.2	332.5
			1931	329.2	345.8
			1932	346.6	362.1
1910	249.7	....	1933	341.8	356.6
1911	254.1	277.3	1934	336.9	351.1
1912	256.9	280.6	1935	341.1	357.2
1913	255.2	278.5	1936	337.3	353.8
1914	255.4	278.5	1937	337.4	355.1
1915	270.7	295.9	1938	356.1	375.8
1916	272.0	295.2	1939	351.2	369.8
Calendar Year			1940	351.1	369.8
			1941	368.5	387.0
			1942	427.8	448.9
1916	278.0	301.2	1943	469.1	490.9
1917	288.2	312.1	1944	473.3	494.3
1918	296.9	320.9	1945	458.1	477.9
1919	308.6	332.4	1946	415.5	433.2

[a] In this table all railroads in the United States are considered as a single system. Data are from *Statistics of Railways*.

associated with the general expansion of the national market at the time. Commenting on this in 1920, the ICC said, "The increases in the average length of haul are possibly accounted for by the absorption of Class III roads and the extension of through billing."[4] The latter reason refers to the possibility that the originating tonnage totals are subject to duplication because rebilled carloads may be reported as originating a second time. The elimination of rebilling may have accounted for some increase in the

[4] *Statistics of Railways*, 1920, p. XXXII.

average haulage figure in this period,[5] but the absorption of Class III or even Class II roads could have had little effect. The 1914-19 increase in haul for Class I is 19 percent, roughly equaling that for all railroads (i.e., Class I, II, and III). In 1921, however, the Commission attributed the lengthened haul to "fundamental economic changes, such, the development of the Western States, growth of exports, and shifting of centers of production and consumption."[6] Whatever the reasons for the lengthening of haul in the period 1914-19, it is difficult (on the basis of the available information) to justify any assumption which would assign a percentage increase in length of haul to any one of our three commodity groups that is more or less than the percentage increase for all three groups. For the period after 1919, however, when highway competition became important, the percentage increase in haul can be distributed over the three groups in some reasonable manner.

The growing importance of motor transport is easily attested to by the rapid growth of motor truck registrations from 900,000 in 1919 to 4,400,000 in 1939, the extraordinary improvement of highway facilities in this period,[7] and other obvious indicators. To what extent has motor truck transport replaced railroad transport? Between 1925 and 1938 the ton-mileage total for all intercity trucking rose from 4 to 40 billion (Table F-4); that for steam railroads fell from over 400 to fewer than 300 billion (Table B-1). To be sure, such figures do not provide any exact measure of traffic diverted from the railroad to the highway. Yet the motor truck had clearly come to play an important role in our transportation system.

The effects of highway competition may well have been felt first in the field of agricultural products, at least for produce intended for local markets, for with the introduction of pneumatic tires and

[5] Such an increase in the figure does not, of course, reflect a real lengthening of the haul, and would be compensated for by a drop in the figure for tons originated.

[6] *Statistics of Railways,* 1921, p. XXXV.

[7] The growth of rural surfaced highway (in thousands of miles) as reported by the U. S. Bureau of Public Roads, is as follows: 1904, 154; 1914, 257; 1921, 387; 1934, 975. Quoted in Federal Coordinator of Transportation, *Public Aids to Transportation,* Vol. IV, p. 4.

the extension of adequate highway facilities, the motor truck quickly displaced the farm horse. The number of farm trucks in use, as reported by the decennial census, increased from 140,000 in 1920 to 900,000 in 1930, with the greatest concentration to be found on the fruit, vegetable, and dairy farms of the Middle Atlantic States, the shores of the Great Lakes, and the valleys of the Pacific Coast States.[8]

In 1916 the proportion of all livestock receipts 'driven in' by truck in the 16 most important livestock markets was less than 2 percent. By 1925 the proportion had risen to 9 percent, then rose rapidly to 22 percent in 1929 and to 42 percent in 1932. In 1939 the corresponding figure for 68 markets was well over 50 percent.[9] Motor transport of fruits and vegetables became common somewhat later. In 1929 the Department of Agriculture estimated that 12 to 16 percent of total shipments were moved by truck instead of rail or boat. It was noted, however, that "on a mileage basis the percentage would be much less because of the longer average haul by railroad." The report indicated too that not all truck transport of produce could be regarded as representing a competitive loss to railway shipping: "Trucks have expedited transportation on short hauls, causing increased production of highly perishable products at points advantageous to desirable markets."[10] Moreover, the products that move largely by truck are, in general, the light, highly perishable, or more valuable ones which pay a high rate by rail. In 1934, 38 percent of all fruit and vegetable shipments to all consuming markets was by truck.[11] The corresponding percentage for twelve important markets in 1938 was 40. Other agricultural products now increasingly shipped by truck are poultry and dairy products. From 1935 to 1939 the truck percentages of all receipts at four markets (New York, Chicago, Philadelphia,

[8] E. G. McKibben and R. A. Griffen, *Tractors, Trucks, and Automobiles* (National Research Project, 1938), pp. 44, 49.

[9] Figures by the Agricultural Marketing Service reported in *Automobile Facts and Figures.*

[10] B. Edwards and J. W. Park, 'The Marketing and Distribution of Fruits and Vegetables by Motor Truck', *Technical Bulletin 272,* Department of Agriculture, 1931, pp. 4, 87.

[11] McKibben and Griffen, p. 113.

and Boston) rose from 17 to 28 for butter, and from 32 to 40 for eggs.[12]

The evidence is clear that, for agricultural products at any rate, the railroads have tended to lose to motor trucking the short haul, perishable, and relatively high priced commodities, the majority of which had previously been shipped by rail at less-than-carload or express rates.[13] That the same tendency obtains for nonagricultural goods is indicated by the National Resources Committee: "In a general way trucks may be said to go after revenue rather than tonnage; to seek finished and manufactured materials and to handle consumer goods rather than capital goods."[14]

The foregoing suggests that the railroads have lost to short-haul trucking items at the upper end of the distribution and retained items at the lower end. A quantitative estimate of the extent of this tendency is afforded by data presented in an ICC report entitled 'Fluctuations in Railway Freight Traffic Compared with Production' (Statement 3951, Nov. 1939). For all commodities carried by railroads, indexes of 'potential tons' were computed by the ICC for the period 1929-38 representing "the number of tons the railways would have carried each year if in such year the railway tonnage had been the same proportion of the total production (adjusted for importation) in the United States as it was in 1928". The ratios of actual tons to potential railway tons were computed. These ratios confirm the hypothesis that such competition has affected LCL tonnage most and bituminous coal least. The 1937 ratios of actual to potential tons, expressed in percentage form, are:

Group I (bituminous coal)	95.6
Group II	76.2[a]
LCL (Group III)	50.0
ALL GROUPS (carload and LCL traffic)	84.9

[a] Average (unweighted) of all Group II commodity percentage ratios.

Data for individual commodities indicate that the correlation between the amount of potential tonnage lost and the revenue per

[12] *Automobile Facts and Figures,* 1940 ed., p. 82.

[13] See also Harold G. Moulton and Associates, *The American Transportation Problem* (Brookings Institution, 1933).

[14] *Technological Trends and National Policy,* p. 184.

ton-mile exists within Group II as well as between Groups I, II, and III. A comparison of ratios of actual to potential tons for 145 commodities in 1937 with the corresponding 1932 revenues per ton-mile yielded a correlation of —0.36. The corresponding normally distributed z coefficient, —0.38, has a standard error of 0.083.

To complete the picture for the period since 1919, the following statement of the Federal Coordinator of Transportation is of interest. Commenting on the fact that over the 12-year period 1922-34 the index of railroad tonnage originated fell more precipitously than the ton-mileage index, he says: "The difference was due to the different distribution of commodities, rather than to a lengthening haul, since it was found that applying the average haul of individual commodities in 1932 to the tonnage of each commodity in each of the preceding twelve years, produced substantially the average haul of all commodities reported by the carriers for that year, indicating that the average haul of the individual commodities in 1932 was the same as that of its preceding years."[15] In other words, the observed increase in average haul for all commodities is due to a gradual disappearance of short-haul commodities from the railroad traffic structure.

Limits of Bias in Our Unweighted Index

We are now in a position to apply our analysis to the periods 1919-32 and 1932-38 to ascertain the degree of overstatement implicit in the unweighted index, which does not adequately emphasize the gradual loss of high-revenue ton-mileage that characterizes this period. The increase in average haul over the period 1919-32 was 6.9 percent.[16] We can assume, on the basis of the above discussion, that the haul of Group I increased by something less than 6.9 percent and the haul of Group III by something more. We can

[15] *Freight Traffic Report*, Vol. II, p. 50.

[16] The 1919 average haul for all groups was 332.4 miles. We have used the 1932 estimate of 355.3 miles based on the *Freight Traffic Report* rather than the ICC figure for 1932 (362.1 miles) because we regard it as the more accurate (see Table C-2). Use of the latter figure, however, involving the assumption of an 8.9 percent increase in average haulage, does not change the results of the analysis significantly.

thus provide an *upper* limit to the degree of overstatement by assuming a 6.9 percent increase between 1919 and 1932 in haul for Groups I and III. This would understate the 1919 Group I haul by assuming too great an increase in length of haul; the 1919 Group III haul, on the contrary, is overstated by assuming too small an increase. The data are set forth in Table C-4.

Table C-4

FREIGHT TRAFFIC: MAXIMUM UPWARD BIAS IN THE UNWEIGHTED INDEX, 1919-1932

	1919			*1932*
Commodity Group (Table C-2)	*Tons Originated*[a] (mil.)	*Average Haul*[b] (mi.)	*Ton-miles* (bil.)	*Ton-miles* (bil.)
I	299.7	339 (min.)	101.6	75.41
II	741.8	323	239.5	144.93
III	54.65	425 (max.)	23.23	7.239
TOTAL	1,096.1	332	364.29	227.58

$e = 0.816$ $f = 0.515$ $S = 1.100$

[a] The Group III figure includes 3.35 million tons, our own estimate (based on production figures) of the amount of originated tons of automobiles and explosives shipped by railroads in 1919.

[b] As explained in the text, the Group I figure is a minimum estimate and the Group III a maximum. The Group II figure is a residual, obtained by subtracting Group I and III ton-mileage from the given total ton-mileage and dividing the remainder by the Group II tonnage originated.

On the present hypothesis e fails to compensate for the low value of f; consequently, the weighted and unweighted indexes diverge. On a 1919 base the unweighted ton-mileage index stands at 64.1 in 1932 (Table 17)[17]; on the above assumptions a weighted index would have declined to 58.3. The unweighted index is seen to overstate the 'truth' — in measuring 1932 output as a relative of 1919 — by 10 percent.

Turning next to the problem of establishing a lower limit for

[17] The ton-mile totals of Table C-4 suggest a slightly different figure because they cover class I roads only and coverage in 1932 is incomplete.

the degree of overstatement, we have again two assumptions at our disposal. We can assume that the Group I haul did not increase (thus establishing a maximum value for the 1919 Group I haul) and that the 1919 Group III haul was the same as that for all groups (so establishing a minimum value for the 1919 Group III haul). We then have the figures in Table C-5 which yield a weighted index of 60.8 for 1932 (1919: 100), about 5 percent less than the unweighted index (64.1; see Table 17).

Table C-5

FREIGHT TRAFFIC: MINIMUM UPWARD BIAS IN THE UNWEIGHTED INDEX, 1919-1932

	1919			*1932*
Commodity Group (Table C-2)	*Tons Originated* (mil.)	*Average Haul*[a] (mi.)	*Ton-miles* (bil.)	*Ton-miles* (bil.)
I	299.7	362 (max.)	108.5	75.41
II	741.8	320	237.6	144.93
III	54.65	332 (min.)	18.17	7.239
TOTAL	1096.1	332	364.29	227.58

$e = 0.877$ $f = 0.653$ $S = 1.055$

[a] The Group I and III average hauls are respectively the maximum and minimum estimates described in the text. The Group II haul is derived from the ton-mile figure, which, as before, is a residual.

Combining results, we have a range for the overstatement of the unweighted index — when 1932 is measured as a relative of 1919 — between the limits 5.5 and 10.0 percent. These limits are at least rough indications of the magnitude of the bias and we can be reasonably sure the true figure lies between them.

It should be noted that in estimating maximum bias at 10 percent, we assume the average haul of bituminous coal increased less than that of all railroad traffic over the period 1919-32, because of the slighter role of motor truck competition. On the other hand, railroad haul of coal may have lengthened owing to regional shifts in coal production. Thus, from 1919 to 1925 West Virginia increased its contribution to total coal production from 17 to 24 percent, while Pennsylvania dropped from 32 to 26 percent; thereafter both states maintained their relative positions, together accounting for about half of all production. It is difficult to determine precisely what effect this shift had on the average haul. As far as New England consumption is concerned, there was probably no change, for such shipments of West Virginia coal would go overland to the tidewater region, thence by boat and again by rail, the total rail haul being about equivalent to that for all rail shipments across the Hudson. The shift might, however, somewhat lengthen the haul to the Great Lakes region, and to this extent would argue for a lower maximum bias than 10 percent.

Table C-6

FREIGHT TRAFFIC: MINIMUM DOWNWARD BIAS IN THE UNWEIGHTED INDEX, 1932-1938

	1938			*1932*
Commodity Group (Table C-2)	*Tons Originated* (mil.)	*Average Haul*[a] (mi.)	*Ton-miles* (bil.)	*Ton-miles* (bil.)
I	225.34	383 (max.)	86.31	75.41
II	530.73	370	195.19	144.93
III	15.79	480 (min.)	7.579	7.239
TOTAL	771.86	376	290.08	227.58

$e = 0.846$ $f = 1.292$ $S = 1.004$

[a] The figures for Group I and III are obtained by multiplication of the corresponding 1932 figures (362 and 454) by 1.058. The Group II estimate is a residual.

For the period 1932-38 the method of analysis is the same. The average haul for all groups increased from 355.3 to 375.8 miles, or 5.8 percent. As before, we assume the increase in Group I to be something less than 5.8 percent and the increase in Group III to be something more. If, however, we increase the 1932 average hauls for Groups I and III by 5.8 percent we overstate the 1938 Group I haul and understate the 1938 Group III haul. The above set of assumptions will exaggerate the decline in Group III, and consequently yield a maximum estimate of the overstatement in the unweighted index for this period. In fact, Table C-6 reports an understatement, of which it furnishes a minimum estimate. The weighted index for 1938 is put at 124.5 (1932: 100) compared with 124.0 for the unweighted measure (Table 17).

This last result is somewhat surprising, for it indicates that the tendency for low-revenue to gain more rapidly than high-revenue traffic was apparently halted and even slightly reversed. The unweighted index (124.0) now understates the truth somewhat, even though the assumption on which the computation is based was designed to exaggerate its upward bias. It would appear that for the period 1932-38 high-revenue traffic, at least as measured by our three categories, no longer lags behind low revenue traffic. Upon closer examination, however, it is seen that the chief increase has been in Group II. We have previously shown that even within Group II the tendency has been to lose high revenue ton-mileage, but our three-group weighting scheme cannot take this factor into account. There is some evidence to support the belief that since 1932 railroad LCL tonnage has been stabilized, in that the railroads have responded to the competitive threat of motor trucking by offering such special services as door-to-door pick-up and delivery.[18] The result has been that since 1933 LCL tonnage originated, while still lagging somewhat behind carload tonnage, no longer exhibits the striking divergence of trend characterizing the earlier period. When it is further considered that the average haul for Group III has probably increased more rapidly than that for other groups, it is clear that this group no longer contributes to the upward bias of the unweighted ton-mile index, and may indeed make for a downward bias, if its average haul has increased to the point where LCL ton-mileage would show a greater percentage increase than the other groups. Such a situation might arise if we assumed no increase in haul for Group I (although there has undoubtedly been some increase due to loss of short-haul coal

[18] The number of railroad owned trucks (exclusive of those owned by Railway Express) used for store-door delivery service increased from 5,500 in 1932 to 48,780 in 1938 (*Automobile Facts and Figures,* 1940 ed., p. 79).

shipments to trucking) and an average increase of 5.8 percent in the Group II length of haul. The Group III haulage figure derived residually on this basis is 836 miles; the calculation may safely be taken to provide an upper limit to the degree of possible *understatement* in the unweighted index.

Table C-7

FREIGHT TRAFFIC: MAXIMUM DOWNWARD BIAS IN THE UNWEIGHTED INDEX, 1932-1938

	1938			*1932*
Commodity Group (Table C-2)	*Tons Originated* (mil.)	*Average Haul*[a] (mi.)	*Ton-miles* (bil.)	*Ton-miles* (bil.)
I	225.34	362 (min.)	81.57	75.41
II	530.73	368	195.31	144.93
III	15.79	836 (max.)	13.20	7.239
TOTAL	771.86	376	290.08	227.58

$e = 0.803$ $f = 0.727$ $S = 1.059$

[a] The Group I figure is equal to the 1932 Group I average haul and is to be regarded as a minimum estimate. The Group II figure is the product of the 1932 figure (347.7) and 1.058 and is probably close to the truth. The Group III figure is derived by subtraction from total ton-mileage and is to be regarded as a maximum estimate.

According to Table C-7, on a 1932 base 131.3 represents a maximum 1938 value for the weighted index compared with 124.0 for the unweighted index (Table 17). That the true value of S lies very much closer to 1.004 than to 1.059 is indicated by the fact that the latter ratio is based on a Group III haulage figure of as much as 836 miles, obviously far too high an estimate in the light of the 476 miles reported by the ICC for LCL traffic as the result of a special inquiry in 1939.[19]

In summarizing the results of the foregoing analysis, we can say that the unweighted index of railroad ton-mileage over the period 1919-32 is subject to an upward bias of 5 to 10 percent, due to the declining share in railroad freight of the relatively high-revenue less-than-carload traffic. In the succeeding six-year period this

[19] *54th Annual Report,* p. 128.

factor no longer made for an upward bias, and may have caused a slight downward bias. However, the possibility still exists that the upward bias continued after 1932, for relatively high-revenue carload traffic within Group II may have been lost. This last factor is not susceptible of measurement, but the probability of its steady operation over the entire period 1919-38 would seem to justify the broad assertion that the unweighted index is subject to an upward bias that is closer to 10 than to 5 percent.